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DAMAGING HYDROGEOLOGICAL EVENTS IN CALABRIA (ITALY): NEW RESULTS OF AN ONGOING HISTORICAL RESEARCH

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Abstract: *Damaging Hydrogeological Events (DHEs) are episodes of severe weather conditions characterised by strong winds, heavy rainfall, landslides, flooding, and sea storms. Each type of phenomenon developing during DHEs is characterized by a proper dynamic and, according to the social and economical framework in which develops, it can cause different impacts on people and properties. Despite during storms all these phenomena occur at the same time (or in a short while), often amplifying damage and hindering emergency management, studies available in literature tend to analyze each type of phenomenon separately, supplying a fragmentary framework of either causes (rainfall) and effects (damage).*

A database concerning DHEs occurred in Calabria (southern Italy) since 1800 has been recently updated, by continuing a historical research which has been started since 2000. Basing on this huge amount of data (more than 10,000 records), an analysis of the series of DHEs occurred in a selected area/period is carried out. Both the methodological framework for DHEs analysis, based on damage classification and a classification of different DHEs types are presented.

Introduction

Periods of bad weather conditions, lasting from one to several days, characterised by prolonged or intense rainfall and strong winds, can trigger almost simultaneous Damaging Phenomena (DP) such as landslides, floods, secondary floods (stagnancy of rain on low permeability surfaces) and sea storms, causing casualties and damages. As a whole, the bad weather periods and triggered phenomena can be defined as Damaging Hydro-geological Events (DHEs) [15, 16, 20, 18].

Since of the simultaneous triggering of various types of phenomena, DHEs represent a source of multiple natural hazards, and need a comprehensive study and management approach. Regarding DP, in the following we focus on landslides, floods and secondary floods (Fig.1). The analysis of triggering rainfall and antecedent meteorological conditions can be the building blocks to outline the main features of DHE and may help to plan, accordingly, a comprehensive defensive strategy.

Still, by comparing triggering rainfall and induced damage, the zonation of the study area according to different *levels of susceptibility to be damaged during DHEs* can be pursued. This information may help in defining priorities for planning hazard mitigation measures [19].



Figure 1. Selected study area (red) as part of Calabria region (southern Italy)

The DP triggered during DHEs can be subdivided into three groups: *landslides* (all artificial slopes, cuts or embankments, excluded) *river floods* (including *flash floods*) and *secondary floods*, as previously defined.

About *landslides*, literature widely recognises that rainfall is the most common triggering cause, even if the relationship between rain and slope instability is not direct [3; 8; 9; 4; 23; 22].

Concerning *river floods*, two types of approaches are available: hydrologic methods and hydraulic methods. Forecasting systems based on hydrologic methods aim to reduce flood damage that exceeds a critical level, while hydraulic methods are based on the modelling of riverbed geometry and the simulation of flood propagation [11]. A historical research can be used to expand flood data, and to define flood prone areas and flood risks [2; 13; 17; 21].

Secondary floods include what is known in the literature as urban flooding [14]; this occurs when rain falls on impervious natural (impermeable soil or rocks) or unnatural surfaces (streets and paved areas), and produces fast-flowing runoff. If the water is not promptly collected into the storm-water system, it can move into the ground depressions and flood them.

Methodology

In the presented approach, DP (landslides, floods and secondary floods) triggered during a series of DHEs are analysed together with the rainfall and meteorological conditions that underlie each analysed DHE. The aim is to point out the features characterising the different types of DHEs that affected a study area in the past and could affect it again in the future. This information can be useful for emergency management agencies in both preventing and mitigating future damage.

The approach is based on the gathering and elaboration of three types of data: a) meteorological synoptic data antecedent to DHEs, b) rainfall data which trigger DHEs, and c) data on damage caused by DP during DHEs. Then, a comparative analysis of collected data allows the individuation of both the types of DHE affecting the area (sorted by severity level), and their temporal trend.

Meteorological Data Gathering and Elaboration

The *meteorological synoptic conditions* preceding a past DHE can be characterised by analysing: a) isotherms, b) geo-potential synoptic maps, c) isobar synoptic maps and d) daily weather reports and forecasts.

Meteorological remote sensing data, available for recent decades, can provide reliable assessments of the evolution of heavy storms over large areas [25]. During the last decades, these data have been published worldwide on a daily basis by meteorological forecasting services, with some local or national differences [24]. Currently, free web and ftp servers supply more than one of these maps per day (<http://www.ncep.noaa.gov> is a useful source).

The meteorological analysis is based on an approach [1; 24] called *expert-eye-scanning* [25]. Traditional analysis of the meteorological data is aimed at defining the typical antecedent meteorological conditions that produce heavy rainfalls. Thus, the individuation of different series of meteorological rainfall and damage patterns, ranked according to the severity of induced damage, can represent an operative guide for emergency management. In fact, detecting the onset of typical meteorological conditions preceding a “type” of DHE allows planning the most appropriate emergency plans.

Rainfall Data Gathering and Elaboration

The measured rainfall data have to be gathered and organised in the climatic database. The availability of long-lasting climatic series, gauge density and frequency of measurements depend on both the country and the study period. Since the end of the XIX century, rainfall data have been gathered in several countries, and currently they can be downloaded from the websites of government agencies.

Since the most widely available type of rainfall data is collected on a daily basis, the Return Period for daily rainfall (T) observed during each DHE could be used to describe the exceptionality of the triggering rainfall. For each gauge, the series of annual maxima of daily rainfall should be evaluated, and the probability distribution function of these values must be assessed. One reliable choice is the GEV (Generalised Extreme Value) probability distribution function [12], which is defined by three parameters that can be assessed using the PWM (Probability-Weighted Moments) method [10; 23]. For each event, according to the maximum values of T , the gauges can be sorted into a few classes of increasing exceptionality, and the results of this classification can be mapped.

Damage Data Gathering and Elaboration

Damage data can be found in sources as *artefacts, chronicles, diaries, local administration archives, archives of local and regional agencies, press archives and scientific papers*. Data gathering requires a time-consuming procedure, and data are affected by several complications [7; 6; 5; 19]. Data availability changes over time: information concerning older events is less plentiful than information pertaining to newer events. Yet, often the greatest amount of data exists for the most severe events, whereas less severe cases are rarely mentioned.

The historical data collected should be uploaded into a database that includes the following fields: a) dates of events; b) municipality where the DP occurred; c) types of triggered phenomena; d) damage description. Then, the *Damage Index of the Event* (DIE), a simplified index taking into account only direct damage caused by DP, can be used to convert damage descriptions into numerical values. Damages are assumed to be the product of the relative *value of the damaged element* and the *level of loss* that it suffered. The relative value of the damaged element ranges from 1 to 10 on an arbitrary scale in which the elements are sorted into nine types (Road network; Railway network; Housing areas; Public buildings; Services networks; Productive activities; Tourist and sport resorts; Hydraulic works; People). The levels of loss have been defined as: L1=high (1), L2=medium (0.5) and L3=low (0.25). DIE is assessed as the sum of all the products of damaged elements by the respective levels of loss caused by all the phenomena that occurred during a DHE.

Comparative Analysis of data

To express, at a regional scale, the impact of each DHE of the historical series, the *Index of Damaged Area* (IDA) can be used. It is obtained by assessing the total *surface* (S) of municipalities hit during a DHE and dividing it by the area of the region. Moreover, assessing their DIE, different DHEs can be classified according to the damage that induced, and finally compared to rainfall data [16].

Applications of the Methodology and final remarks

One of the first applications of the methodology was carried out on a test site (686 km²) named Locride (L), located in SW-Calabria (Southern Italy) [16]. Basing on 24 DHEs, occurred during an 80-year period, four types of DHEs characterised by increasing severity levels were individuated (Fig. 3).

Type A_L hits the coastal sectors between November and January, and causes river outflows and/or wide-spread secondary flooding. Critical rainfall durations range between 1 and 20 days, and T_c (return periods of cumulative rainfall) are less than 10 years. The damage severity is low.

Type B_L hits the internal sectors, and generally happens between January and March, after rainfall having T_c<30 years. Triggered phenomena are landslides, sometimes coupled with secondary floods. Damage ranges from low to medium.

Type C_L, occurring between October and January, causes all types of DP. It hits from the inlands to the coast both central and southern part of the area. Rainy periods that last less than 60 days: the highest cumulative rainfall lasts less than 30 days and has T_c<50 years. Damage is from medium to high.

Type D_L, occurs between October and December, and causes damage through the area. The critical duration of triggering rainfall is less than 60 days and T_c>50 years. Social and economic impact is strong: damage is high and victims are numerous.

All the types of DHEs were observed from September to February, and the only one occurred in February was very brief. During each DHE, the centres of low-pressure area always developed between western Europe, the western Mediterranean Sea and north Africa, and moved slowly, dissolving eastwards or northeastward. The cyclonic conditions were almost stable for some days or suffered short breaks.

Ten DHEs were due to the antecedent appearance of relevant low-pressure fields in two different areas to the west. The former low-pressure field is generally located between northwestern Africa and Spain, while the latter is located northward, between the western Mediterranean Sea and western Europe. The former low-pressure field ensured the inflow of African masses of warm air, while the latter caused the inflow of very cold air masses. These antecedent conditions have been called the “double effect” to distinguish it from the usual precipitation linked to the simple movement of Atlantic depressions. Because of the double effect, extremely exceptional daily rainfall was observed in many DHEs. The assessed T peak values were greater than 200 years in six DHEs.

If the number of victims is used as an event's severity indicator, floods are the most severe DP. The 196 fatalities during the 85-year analysed period were caused primarily by floods (77%) and subordinately by landslides (23%).

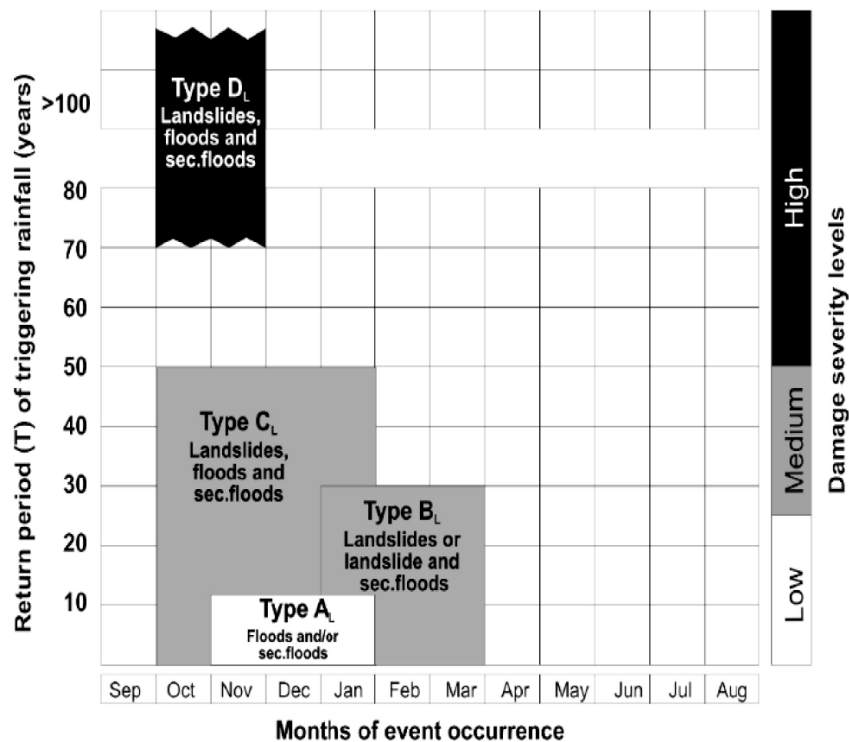


Figure 2. Types of DHE occurring in the Locride area (Calabria, Italy), characterized using return period of triggering rainfall, month of occurrence, damage severity and type of triggered phenomena [16]

Concluding remarks

Damaging Hydrogeological Events are a source of multiple hazard, as they can simultaneously trigger different types of damaging phenomena, such as landslides, floods and secondary floods. Hence, a comprehensive approach, which covers all kinds of phenomena, has been designed to reveal relationships with the concurrent triggering rainfall and antecedent meteorological conditions.

The methodology classify DHEs in terms of recurrence, damage severity and localisation of the affected area. It is based on the assessment of indices, which describe the exceptionality of rainfall and the level of damages of each DHE, and tie these aspects to their triggering meteorological conditions by aiming to individuate the typical DHEs affecting a study area.

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REGIONAL INFORMATION-MEASUREMENT SYSTEM FOR CONTINUOUS MONITORING OF ATMOSPHERIC GROUND LAYER AND FORECASTING OF DANGEROUS WEATHER PHENOMENA

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Abstract: Methodological and instrumental bases are considered for designing a prototype information measurement system (IMS), intended for monitoring and forecast dangerous weather phenomena over territory up to several hundreds square kilometers. The IMS developed and the results obtained are discussed.

Regional monitoring of meteorological fields for forecasting dangerous weather phenomena (DWP) such as hurricanes, squalls, transports of pollutants resulting from technogenic catastrophes are so far a complicated problem. This is due to a sparse Roshydromet observation network, long periods of updating the information on this network (every 3 hours), and a low level of usage of available meteorological forecasting models.

The information-measurement system (IMS) for regional DWP detecting was designed on the basis of ultrasonic weather automatic stations (UWAS) AMK-03 in the IMCES SB RAS [1, 3]. UWAS AMK-03 measures the main meteorological magnitudes at the sampling frequency up to 80 Hz and averages the mea-